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X-RAY STUDIES OF STRESSES IN METALS

new explanation of residual strain balancing

RECENT work at the National Bureau of Standards has provided new information on the distribution of stresses between crystals in a metal. Studies of changes in the lattice spacing of crystals, both under load and after release from load, were made by X-ray diffraction. It was found that the magnitude and direction of the principal stresses can be computed for a certain loading condition in this way even though the elastic limit has been exceeded. The investigations have also led to a new explanation of the balancing of residual strains. These results should not only increase the practical utility of stress measurement by X-ray diffraction but should also prove useful in basic studies of metal fatigue and corrosion.

Commonly used metals are made up of a large number of very small crystals. When a stress is applied to such an aggregate, the behavior of individual crystals depends on the orientation of the axes of the crystal relative to the direction of the stress. If the crystals are randomly oriented, then the individual effects are averaged out and the metal behaves in a nearly homogeneous manner. However, the distribution of stress is not uniform from one crystal to the next, and it is important to measure these microscopic stresses in order to understand better such phenomena as fatigue and stress corrosion, which are restricted in their early stages to a single crystal or to the boundary between crystals.

By means of X-ray diffraction it is possible to measure the distance between atomic planes with considerable accuracy. The presence of a stress causes a change in the interplanar spacing; thus X-ray diffraction provides a strain gage for the crystal lattice. It is highly selective as only those crystals are measured that have a certain orientation relative to the X-ray beam, but by making the measurements with a number of different directions of incidence of the beam, it is possible to study the strains in a high percentage of the crystals. Only elastic strains are measured, as plastic strain occurs without further change in interplanar spacing.

Previous work at the Bureau and elsewhere had shown that there is a certain range of applied stress over which the crystal lattice behaves elastically; beyond this point the strain as measured by X-rays remains nearly constant although the metal continues to deform. Also, when the load is released, a residual strain is left, opposite in sign to that under load. The present investigation sought to answer such questions as the following: (1) Is the elastic limit the same in all directions relative to the applied stress? (2) What is the nature of the residual strain observed after plastic deformation and how is the stress causing this strain balanced?

To provide the necessary data, an investigation of lattice strain in 17 directions in a low-alloy steel was conducted by H. C. Vacher, R. Liss, and R. W. Mebs

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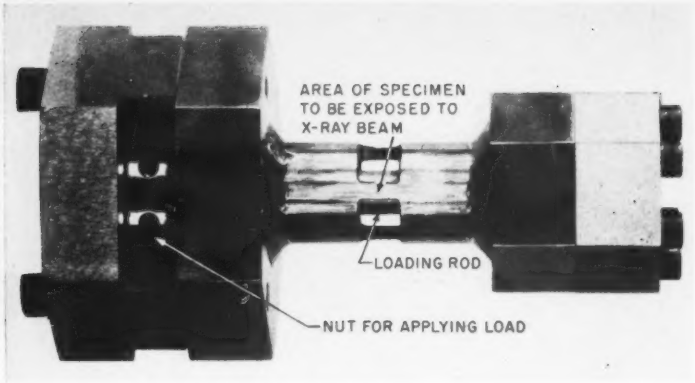


Specimen and loading system used to study the distribution of stresses between crystals in a metal. The specimen is essentially a hollow cylinder with portions machined away to leave three triangular legs. The nut threaded on the loading rod applies a compressive load with a clockwise turn and a tensile load with a counterclockwise turn. In the complete assembly the specimen and loading system are mounted on a two-circle goniometer. An X-ray beam strikes the surface at any desired angle to measure interplanar space changes caused by strain.

of the Bureau's mechanical metallurgy laboratory.[1] Measurements were made both under load and after release of load, the successive loads being of increasing magnitude. The specimen was essentially a hollow cylinder—$\frac{7}{8}$ in. in outside diameter, 2 in. long, and $\frac{1}{8}$ in. in wall thickness—with portions machined away so as to leave a reduced section consisting of three symmetrically spaced legs $\frac{3}{8}$ in. long and triangular in cross section. This type of design was adopted so that the specimen would be stable in compression and would not require large loads to obtain high stresses. The ends of the specimen were welded to supports for a central loading rod. A nut was threaded on to the loading rod so that a clockwise turn applied a compressive load and a counterclockwise turn applied a tensile load. Because the nut and the far end of the loading rod made contact with the specimen supports through spherical surfaces, the load was distributed equally and axially on the three legs. The load was measured by wire strain gages attached to the calibrated loading rod.

The specimen and loading system were mounted on a two-circle goniometer so that the X-ray beam could be made incident at any desired angle relative to the specimen surface and the stress direction. Special precautions were taken so that the surface on which the strain measurements were made would have the same structure as the interior and would be initially free from strain. The diffraction patterns were recorded photographically and measured with a photoelectric micrometer developed for this purpose. In order to improve the inherently poor precision of the strain determinations, three patterns were exposed for each loading condition, and the strain values were computed from the average of measurements on all three.

A change in lattice spacing causes a change in the

In apparatus for X-ray measurement of stresses between the crystals in a metal, the beam emerges through a pinhole at the center of the circular film holder. When a load is applied to the specimen directly in front of the holder, the strain causes a change in the X-ray diffraction pattern.

diffraction angle, θ, so results of the experiment were summarized in diagrams showing the change in $-\tan 2\theta$ with load. At low stresses the graph of $-\tan 2\theta$ versus load is a straight line, the slope of which is termed the lattice compliance. Deviations from this compliance line (i. e., the elastic limit) occur at lower stress for the positive compliance (stress and strain acting in the same sense) than the negative. This was found to be generally true in all directions investigated. The average stress values at which the deviations occurred were 23,000 and 40,000 lb/in.^{2} for positive and negative compliances, respectively.

A study of the variation of lattice compliance with direction indicated that shear and transverse stresses were superposed on the loading stress. Analysis showed that if such stresses were assumed to be proportional to the loading stress, then the experimental values of compliance could be adequately represented by an equation derived from the elastic theory for a homogeneous medium. This implies that the ellipsoid of elastic strain is the same in all crystals measured, from which if true, it can be deduced that there are steep stress gradients in the vicinity of the crystal boundaries.

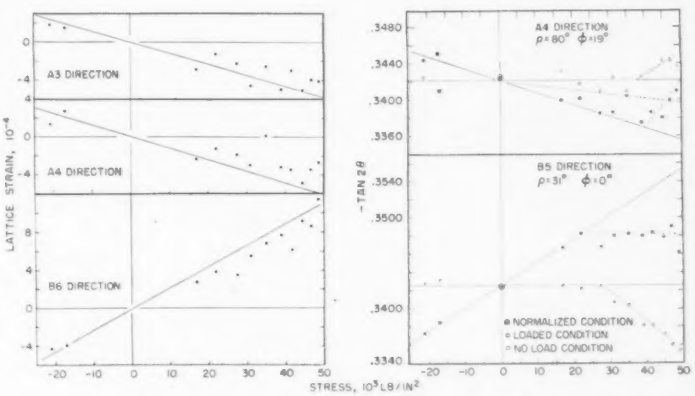
As previously mentioned, the residual strains on release of load beyond the elastic limit are opposite in sign to those under load, moreover, they increase with increasing load. It was found that the values obtained for the difference in tan 2 θ, expressed as strain, which occurred on release of load for stresses greater than the elastic limit, could be predicted from the lattice compliance computed from above-mentioned equation. This indicates that the magnitude and directions of the principal stresses can be computed for a certain loading condition from the change in lattice spacing on release of load even though the elastic limit has been exceeded.

The other investigators had previously noted the development after plastic deformation of residual stresses opposite in sign to the applied stress, and various explanations have been offered to account for the necessary balancing stress. One theory is that the stresses are due to the anisotropic behavior of individual crystals and are balanced by opposite stresses in adjacent crystals of different orientation. The Bureau's results do not support this theory, as a wide range of orientations were studied and all of the residual strains appeared to arise from a single stress system.

It has also been suggested that the observed stress occurs only in the surface layers of the plastically deformed specimen, the balancing stress being present in the interior. A study [2] conducted by C. J. Newton and H. C. Vacher of the Bureau staff indicates that this theory does not hold. Two specimens of ingot iron were plastically deformed, one in compression, the other in tension. Sections were cut from the bars at angles of 0°, 30°, and 90° to the axis along which the stress had been applied, and X-ray strain measurements were made on the surfaces of these sections. Assuming that cutting of the specimen relieved the stresses normal to the new surface and that stresses parallel to this surface were not affected by the sectioning, it was possible to reconstruct the residual stress system existing in the bars before they were cut. These were found to be similar to those found previously on the outside of specimens, namely a compressive stress in the tensile specimen and vice versa.

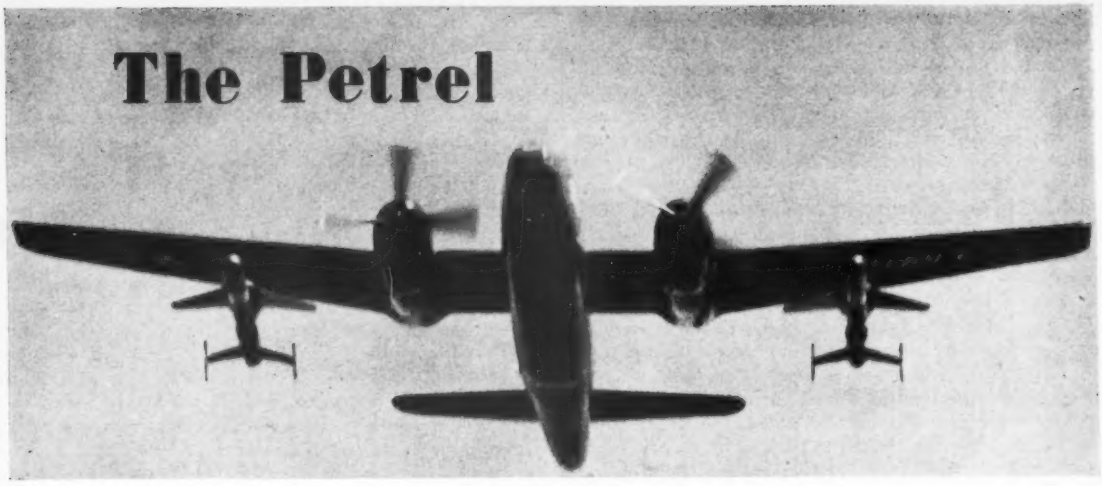
As the experimental results do not agree with any of the current theories, the NBS investigators propose the following explanation for the balancing of the observed residual strains: it is suggested that this balancing is supplied by stresses in material in which the crystal lattice is so distorted that it does not scatter X-rays coherently. Such material might be found at grain boundaries or in slip bands.

Left: **Total change in lattice spacing on release of load plotted against a previously applied load. Slopes or compliances of solid lines were computed from equation for elastic behavior of a homogeneous medium. This implies that ellipsoid of elastic strain is the same in all crystals measured, thus indicating steep stress gradients in the vicinity of crystal boundaries.**
Right: **Experimental results from studies on strains in metals. Strain values after load was released are plotted on abscissa values corresponding to load. When strain measurement was made in direction nearly perpendicular to crystal surface it was found that strain was compressive when applied stress was in tension, and vice versa. At angle of 31° stress and strain were in same sense.**



[1] *For further technical details, see* Elastic and plastic behavior of the ferrite lattice in a low alloy steel, *by H. C. Vacher, R. Liss, and R. W. Mebs (to be published in Acta Metallurgica).*

[2] Residual lattic strains in sectioned bars of plastically deformed iron, *by C. J. Newton and H. C. Vacher, J. Metals* **7**, *1193 (1955).*



An Air-to-Surface Guided Missile

AN air-to-surface guided missile, developed by the Bureau for the Navy Bureau of Ordnance, is now in operation with the fleet. Known as the PETREL, the missile is designed primarily for use against enemy ships at sea. Launched by patrol aircraft well outside the range of the target's air defense, the PETREL attacks at high speed and with devastating effect. Use of the missile will thus save the plane pilot from the antiaircraft hazards which attacking planes met in World War II when they closed the target. The PETREL is shown above suspended from the wings of a P2V Neptune aircraft.

Work on guided missiles constituted one of the major NBS war activities. By 1947 the concept of the PETREL, essentially as it is at the present, was approved. Contracts were placed with industry for development and production of major components under the Bureau's general technical supervision.

A long period of research and engineering then ensued, during which the PETREL approached the final production engineering stage. By 1951 it was ready for the production line, and a contract was placed with the Fairchild Guided Missiles Division for service engineering and production of the missile under the supervision of the Naval Ordnance Experimental Unit. NOEU is a field activity of the Navy Bureau of Ordnance and has the technical responsibility for the serviceability and utility of PETREL. In 1953, the first service-engineered model was delivered and flight tested. The Navy reported that the missile performed with a degree of reliability considered exceptionally high for such a technically advanced weapon. Subsequently, large numbers of the missile have been built, flight tested, and improved to produce the PETREL now being used by the Navy.

Up until 1951, the NBS work on PETREL was conducted in Washington in the Bureau's Ordnance Development Division. At that time, the staff unit engaged in this work was moved to Corona, California to occupy a new facility which had been made available through a special appropriation by the Congress. In 1953, the Corona Laboratories were transferred to the Department of Defense and are now operated as a Naval Ordnance Laboratory.

Addition of the new missile fills out the Navy family of missiles for fleet use and gives the Navy four missile delivery capabilities. They are (1) air-to-surface (the PETREL), (2) air-to-air (the SPARROW), (3) surface-to-surface (the REGULUS), and (4) surface-to-air (the TERRIER). (Official United States Navy Photograph)

Forward Scatter Addendum

In *Forward Scatter of Radio Waves*, February 1956 issue of the Technical News Bulletin, it was stated that tower and airborne microwave refractometer measurements were made in the Colorado area with a refractometer developed at the National Bureau of Standards. This statement is misleading in that only the tower measurements were made with the refractometer developed by the Bureau. The airborne refractometers were developed by the University of Texas and carried aloft in flights by personnel from Wright Air Development Center and Air Force Cambridge Research Center.

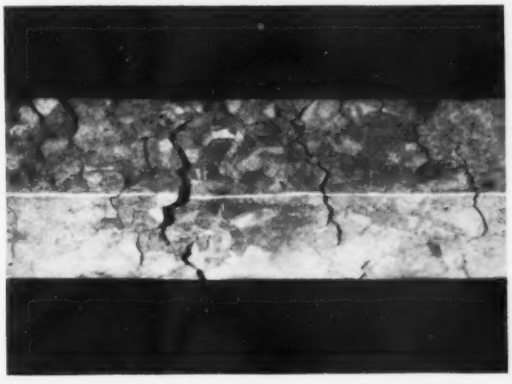
Stress-Corrosion Cracking of Brass

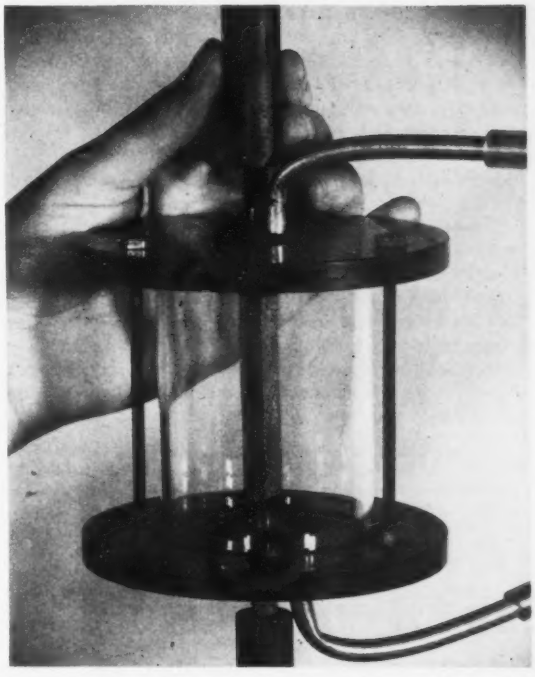
STRESS-CORROSION CRACKING has been a problem in the production of wrought-brass articles for many years. During spinning or deep drawing of brass cups, lamp bases, and the like, stresses are set up which remain in the metal unless removed by annealing. Then, if the brass is stored in an atmosphere containing small amounts of ammonia and water vapor, stress-corrosion cracking may occur. Even very small amounts of ammonia, such as are found in the average home atmosphere, may be sufficient to cause this effect. Industrial atmospheres can be even more corrosive.

Although wide investigation has produced many explanations for the stress-corrosion mechanism in other metals, little is definitely known about the process as it occurs in brass. The action is generally considered galvanic, but its mechanism is not understood. Seeking to extend basic knowledge in this field, H. L. Logan of NBS recently made a study of the relationship between crystal orientation and stress-corrosion cracking in alpha and beta brasses.[1] His results indicate that crystal orientation has an important influence on the galvanic action which causes stress-corrosion cracks.

The Bureau study included direct observation of test specimens. These were prepared with crystals large enough for visual inspection—⅛ in. or larger. Two compositions of alpha metal were studied: Cartridge brass (70% copper, 30% zinc) and commercial bronze (90% copper, 10% zinc). The alpha phase is found in most fabricated articles, often with small grains of the beta phase (50% copper, 50% zinc) scattered through the matrix. The specimens were machined with square cross sections and exposed to an atmosphere containing ammonia gas, carbon dioxide, water vapor, and air. Tensile stresses of 5,000 to 6,000 lb/in.^{2} were applied until stress-corrosion cracks appeared.

Cracks approximately normal to the length of the specimen, extending into adjacent faces from a corner, were studied by X-ray diffraction techniques. It was found that the crystallographic planes bounding the cracks are randomly distributed so that cracking is not due to corrosion attack along particular crystal planes.





Brass specimen in circulating-atmosphere cell for study of stress corrosion. A controlled atmosphere of ammonia, carbon dioxide, water vapor, and air enters through lower tube and is removed through the upper. Stress is applied to the specimen through the rods at the top and bottom of the cell.

The data also show that the stress-corrosion cracking of alpha brass is most probable at those crystal boundaries that have the highest energy because of relative orientation of the adjacent crystals. As the attack progresses at a particular grain boundary, points of stress concentration are localized and a suitably oriented stress pattern causes rupture of the protective film on the metal at the apex of the attack. Previous work has shown that film-free alpha brass is approximately ½ volt anodic to brass covered with an atmospherically formed film or with corrosion products.[2] Thus, a galvanic cell is set up with metal going into solution and forming the stress-corrosion crack at the anode. The attack will continue until a change in the stress pattern or other factors permit the protective film to reform at the anode.

Part of a specimen of alpha brass containing intercrystalline stress-corrosion cracks. The specimen has been subjected to tensile stress parallel to its long axis. Cracks studied extend from the edge of the specimen into the two adjacent surfaces.

Beta-brass specimens were tested and studied in the same way. It has been reported that crystal boundary energy in beta brass is smaller than in alpha. Thus there might be less chance that a crack would start at a specific crystal boundary in the beta alloys. Results of the Bureau's tests support this idea. Most stress-corrosion cracks were transcrystalline. Those cracks which began at grain boundaries soon became transcrystalline. The data indicate that crystals containing stress-corrosion cracks were more favorably oriented for deformation under applied stress than randomly oriented crystals in, for example, an unused test specimen. Thus it is suggested that applied stress produces microscopic deformation in most favorably oriented crystals. Deformation then ruptures the protective film on the crystals and stress corrosion proceeds by the same process as that suggested for alpha brass.

Unless conditions permit film repair, stress corrosion in both alpha and beta brasses may proceed to complete failure in a relatively short time. If the film is restored and stresses are not increased or readjusted, stress corrosion may cease.

[1] *For further information, see* Relationship between crystal orientation and stress-corrosion cracking in alpha and beta brasses, *by H. L. Logan, J. Research NBS* **56**, *159 (1956) RP2662.*

[2] *For further technical details, see* Film rupture mechanism of stress-corrosion, *by H. L. Logan, J. Research NBS* **48**, *99 (1952) RP 2291.*

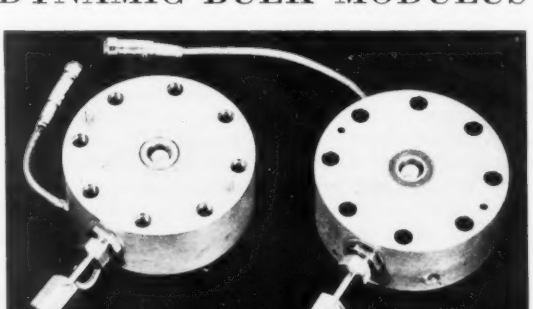
Typical stress-corrosion cracks in a brass lamp base.

DIRECT MEASUREMENT OF DYNAMIC BULK MODULUS

AN APPARATUS that measures directly the dynamic bulk modulus of solids and liquids has been developed at the Bureau. Designed primarily for studies of the compressibility of polymeric materials as a function of time or frequency of application of pressure, the instrument makes possible for the first time the study of such properties with reasonable precision over a frequency range of 50 to 5,000 cps. It should thus prove useful in studying transition phenomena with time scales of the order of 0.02 to 0.0002 second. It should also prove useful in permitting measurements that will supplement ordinary PVT measurements on materials whose compressibility is independent of time or frequency. The development of this apparatus was carried out by J. E. McKinney, E. Edelman, and R. S. Marvin of the NBS staff as part of a program of basic instrumentation sponsored by the Department of Defense and the Atomic Energy Commission.[1]

The bulk modulus of a material is defined as the ratio of applied pressure to the fractional change in volume caused by this pressure. When pressure and change of volume vary sinusoidally with time, the corresponding steady state ratio is the dynamic bulk modulus. The reciprocal of the bulk modulus is defined as the bulk compliance or compressibility.

A dynamic bulk compliance so defined will consist of two parts. The real part, defined as the component of the volume change in phase with the pressure divided by the pressure, measures the energy stored during a deformation, and corresponds very nearly to the static compliance measured on application of a steady pressure. The imaginary part, defined as the component of volume change 90° out of phase with the pressure divided by the pressure, measures the energy lost during a deformation.



Apparatus for measuring directly the dynamic bulk modulus of polymers and other materials. The two halves of the steel cylinder have been opened up to show the bulk modulus cavity in the center. Note the two piezoelectric crystals, one in each side of the cavity. One of the crystals generates cyclic changes in volume; the other detects the resulting changes in pressure. Needle valves at the side of each half are used to seal the cavity after filling with a pressure transmitting fluid. The copper ring surrounding the central hole in the right half fits into a mating groove in the other half, so the cavity can be sealed against pressures up to 1,000 atm.

At the frequencies used with this apparatus, many materials, such as metals, have a dynamic bulk com-

pliance that is independent of frequency and has nearly the same value as would be calculated from the change of volume associated with a static pressure. For other materials, such as polymers near their glass transition temperatures, the dynamic bulk compliance depends on the frequency of the test and contains an imaginary component. The existence of such an imaginary component indicates the presence, under the conditions of the test, of some basic molecular mechanism which is of fundamental interest. The chief purpose for which this apparatus was developed was to study the effect of static pressure and of temperature on the complex bulk compliance at a given frequency and by this means to investigate the basic molecular mechanism. Of secondary importance to the basic program, but perhaps of real importance in other investigations, will be evaluation of the bulk moduli of various structural materials, because the bulk and shear moduli together determine the response of an isotropic, homogeneous material to any arbitrary small stress or strain.

The apparatus consists of a cylindrical cavity, about 1.5 cm in diameter and 1.5 cm deep, inside a heavy steel block. Two piezoelectric crystals are mounted within the cavity, one to serve as a driver or generator of volume velocity, the other as a detector of alternating pressure. The sample to be measured is placed within the cavity and the remainder of the cavity volume is filled with an oil to act as a pressure-transmitting fluid.

When a sinusoidal voltage of about 50 volts is applied to the driving crystal, its volume changes sinusoidally with the same frequency as the applied voltage, thus changing the volume of the cavity available to the sample and confining liquid. The frequency is always kept sufficiently low that no wave motion is set up in the small cavity. Pressure is thus uniform throughout the whole cavity at any instant and is determined by the compliance of the sample and confining liquid. The apparatus is calibrated by using a sample and a confining liquid of known compressibility.

The real and imaginary parts of the dynamic bulk compliances of the sample, plus those of the transmitting liquid, plus contributions from the apparatus itself, are proportional to the real and imaginary parts of the ratio of driving to pickup voltage. The quantities are measured with an a-c potentiometer, in which the driving voltage is attenuated in two stages, one involving a phase adjustment. The attenuated voltage is then balanced against the pickup voltage, using as a null indicator a high-impedance battery-operated preamplifier followed by a frequency analyzer to reduce noise. As the crystals are operated far below their resonance frequency, the pickup signal is very low—a few tenths of a millivolt—and for a good balance a null must be obtained to within less than 1 microvolt.

The apparatus is constructed so that a static pressure as high as 1,000 atmospheres can be superposed on the alternating pressure. The alternating pressure is so low that the instrument measures a differential compliance, or a tangent to the volume-pressure curve at the particular static pressure superposed. Because of the frequency range in which it is operated, it measures an adiabatic rather than an isothermal compliance.

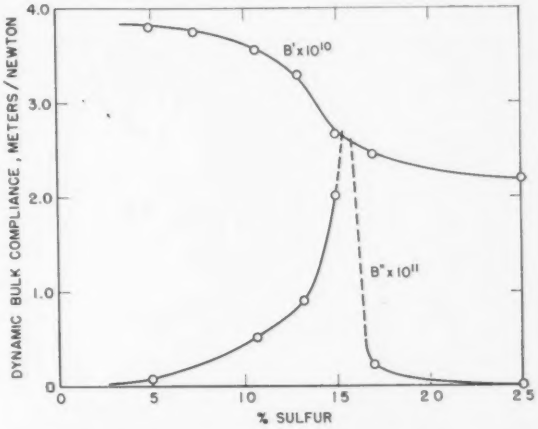
Because the wavelength used must be large compared to the size of the cavity, the top frequency limit is about 5,000 cps. Satisfactory operation of the potentiometer imposes a lower frequency limit of about 50 cps.

In calibrating the device, steel, magnesium, and hard rubber have been used as materials of known compliance, with a vacuum-pump oil as the transmitting medium. The results on all possible pairs of these four materials (which have negligible loss under the conditions of measurement) are in excellent agreement. In fact, they agree with the compliances obtained from other measurements to within the estimated errors.

The basic measurements, corresponding to the difference in compressibility between the sample and confining liquid, have estimated standard deviations of a little under 1 percent. Measurements are fairly rapid; about 1 day is required to cover the frequency range available and 3 or 4 different static pressures, and about the same time is required to calculate the results. The present apparatus is limited to operation at room temperature, but a modified version now under construction should be usable between $-30°$ and $+100°$ C.

The present apparatus has recently been used to investigate glass transitions in the system natural rubber-sulfur. Results indicate that at 25° C, in the time scale of 0.01 to 0.001 second, and at about 50 atmospheres, the "transition" between rubberlike and glasslike behavior occurs for 15 percent sulfur, as compared to 18 percent sulfur for the transition as ordinarily measured. Further experiments to evaluate this behavior more exactly will be possible with the modified apparatus as the temperature can then be varied also.

[1] *For further technical details, see* An apparatus for the direct determination of the dynamic bulk modulus, *by John E. McKinney, Seymour Edelman, and Robert S. Marvin, J. App. Phys.* **27**, *425 (May 1956).*



Real and imaginary parts of the dynamic bulk compliance in square meters per newton ($=10\times cm^2/dyne$) for the system natural rubber-sulfur at 700 cps, 200 atm static pressure, and 25° C. The upper curve represents the real part (B′) of the compliance while the lower curve represents the imaginary part (B″). The exact location of the maximum in the lower curve is not known. This portion is indicated by a broken line.

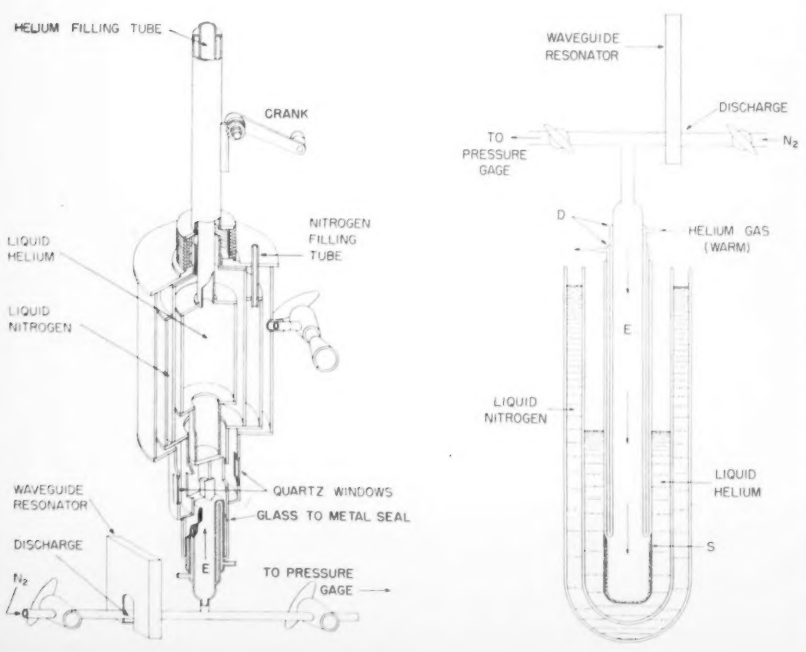
Low-Temperature Storage

THE National Bureau of Standards has developed a technique for capturing and storing large numbers of highly reactive molecular fragments at temperatures near absolute zero. By this method, unstable atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped in solid form. Because these atoms are frozen in the excited state, they can be conveniently studied by optical spectroscopy.

In experiments to date, the Bureau has produced solids containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy (OH) molecule. These solids have very unusual properties, emitting bright glows, blue "flames," and colored flashes of light. When warmed 20 or 30 degrees, they combine very actively, releasing large quantities of stored energy, principally as heat. Possible fields of application include solid state physics and basic chemistry. Here the trapped atoms could be used as powerful probes into the solids containing them. From a study of their properties, information could be obtained about the arrangement of the atoms and molecules in the solid and about the forces acting on them. The mechanism of atomic diffusion and of reactions between atoms and molecules also could be studied.

These experiments were begun at NBS in 1954 by H. P. Broida and J. R. Pellam [1] and are being continued by H. P. Broida, A. Bass, and O. Lutes [2] of the Bureau's temperature measurements laboratory. C. M. Herzfeld of NBS is carrying out theoretical investigations [3] on the systems. The research is supported chiefly by the Office of Naval Research and the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.

Within the last 5 years, several methods have been developed in other laboratories for stabilizing free radicals at low temperatures. However, the present technique has the advantage that the free radicals are stored in highly excited states as a result of the electric discharge, making it possible to study and analyze them by spectroscopic techniques. Also, because the radicals are collected at much lower temperatures than in previous methods, they can be stored longer in the uncombined form.

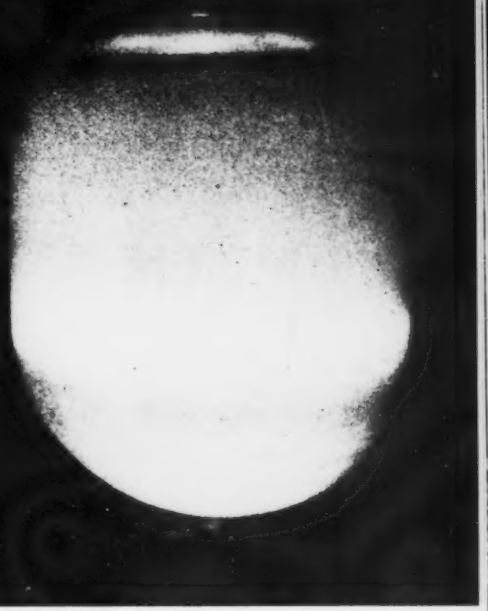


Left: **Apparatus, designed at the Johns Hopkins Applied Physics Laboratory and modified by NBS, for collection and spectroscopic observation of free radicals at low temperatures. Nitrogen or other gas is admitted through the stopcock at lower left and passes through an electrodeless discharge in the waveguide resonator. The gaseous products of the discharge are collected in solid form on the quartz windows, which are kept at 4.2° K by thermal contact, through copper bars, with the liquid helium reservoir. Metal Dewars are used for both liquid helium and liquid nitrogen.** ***Right:*** **Schematic diagram of apparatus used for collecting and storing free radicals at very low temperature. Nitrogen or other gas is admitted through the stopcock at upper right. It then passes through an electrodeless discharge in the waveguide resonator, where it is broken up into free radicals. The surface S, immersed in liquid helium, acts as a trap, freezing out all gases except helium among the discharge products at 4.2°K. To prevent solidification of the discharge products at temperatures above 4.2°K, warm helium gas is passed between the compound walls of the tube E. The liquid nitrogen in the outer flask helps to insulate the liquid helium.**

Free Radicals

Excited Atoms

Trapped in Solids



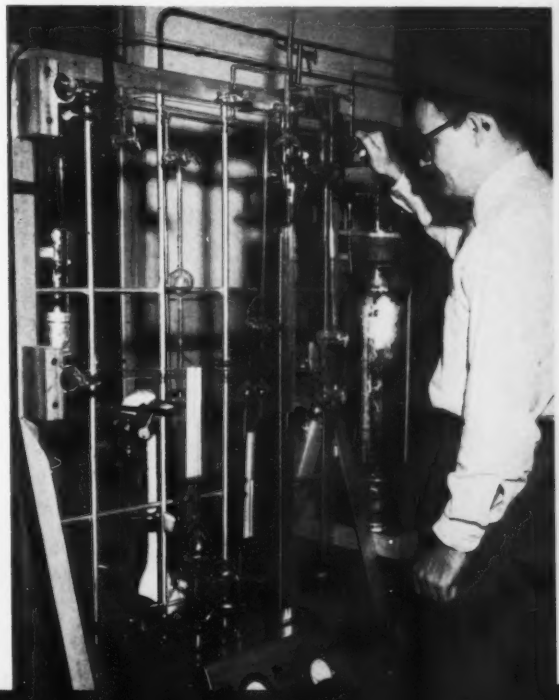
Above: **The glow from atomic nitrogen frozen into a solid a few degrees above absolute zero. The glow is normally bright green but tends to become yellow when flow of gaseous nitrogen is increased. The solid nitrogen was obtained by passing molecular nitrogen gas through an electric discharge, then freezing the resulting free atoms into a solid by contact with a very cold surface. The atomic nitrogen was thus captured in the excited state, making it possible to study it from the light it emits.**

In this method, gases containing molecules of nitrogen, hydrogen, oxygen, or water are first passed through a high-frequency electric discharge, then frozen very suddenly at 4.2° K, just a few degrees above absolute zero.

The discharge is maintained in a waveguide resonator by a 2,450-Mc power supply. From the resonator, a glass tube leads the resulting molecular fragments into an evacuated metal vessel containing a cold surface in contact with a liquid helium bath. To prevent solidification of the discharge products at temperatures above 4.2° K, the gases are carried to the cold surface through a passageway that is kept near room temperature by contact with warm helium gas. When the gases reach the cold surface, they freeze into solid form there.

Various techniques can then be used to study the resulting solids. Through windows in the metal vessel, a number of spectrographs of different types can be aimed at the cold surface, and the light given off by the solids frozen on the surface can be analyzed. To study the light absorbed by the solids, the gases are condensed on a transparent cold surface, and light is passed through the windows of the vessel, the condensed material, the cold surface, and finally into the spectroscopes. To determine the heat evolved by recombination of atoms, the gases are condensed into a small, simple low-temperature calorimeter, and the heat evolved by the material as it warms up is measured.

Because the free radicals produced by this method can be kept unchanged for many hours, a more detailed study of their properties has been possible than in previous work. For example, during the discharge through nitrogen the condensed solid emits a bright green glow, which tends to become yellow at high flow rates. The spectra obtained from this glow show that the structure of the solid condensed from the discharge differs from that of ordinary solid nitrogen. In fact,



Apparatus for studying heat energy produced by recombination of frozen free radicals. Free radicals are collected in solid form in calorimeter within Dewar flask (right). Warming of frozen solid causes stored atoms to combine very actively. Calorimeter measures heat energy released.

Apparatus for studying free radicals at temperatures near absolute zero. Large metal cylinder (center) contains liquid helium in thermal contact with cold surfaces below on which frozen free radicals are deposited. Light emitted by the solids thus deposited can be observed through quartz window below the cylinder and is analyzed on spectroscopes (left foreground).

each atom of the condensed nitrogen forms a very loosely bound complex with some neighboring molecule, and this complex has properties that differ from those of the separate atom and molecule. The evidence shows that the complex is a definite unit. By analyzing its spectra, the forces holding it together can be studied.

Brilliant blue flashes are also observed from the solid surface during the nitrogen discharge. These flashes are thought to be due to local warming. After the flow of nitrogen is stopped. the discharge goes out and a green afterglow from the cold collected material persists for several minutes, decaying with a halflife of about 15 seconds. When the green afterglow has disappeared, sudden warming of the vessel walls (to between 25° and 35° K) causes a blue "flame" which appears to "burn" through the condensed material. The light and heat thus given off are evidently due to recombination of the atoms into molecules. When the light is analyzed spectroscopically, it gives information about the structure of the molecule just formed and about the forces acting between two atoms. The reaction of a nitrogen atom with an oxygen atom can also be studied in this way.

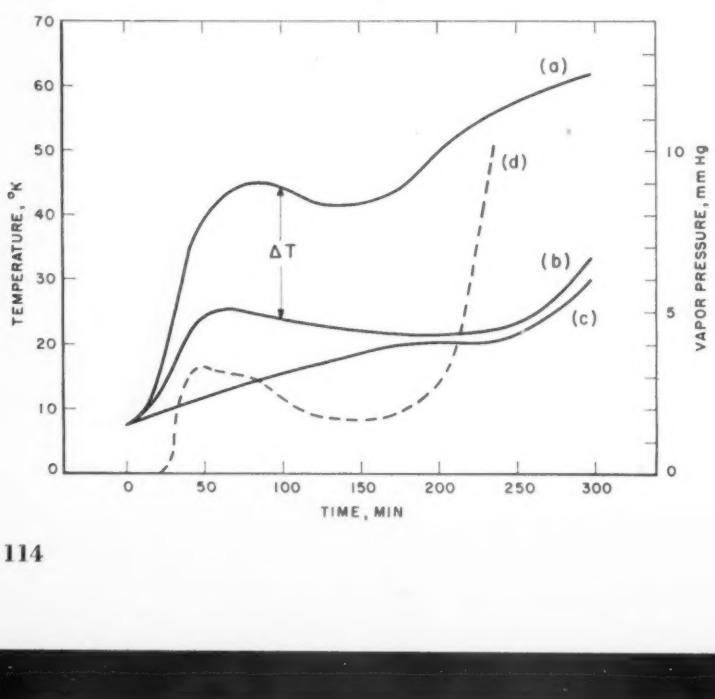
When oxygen is passed through the discharge, a clear, glassy deposit is obtained which has rather complex absorption spectra. Upon warming this material to about 20° K, the original deposit evaporates and a solid violet material condenses on the surface. This substance has been identified as a mixture of oxygen and ozone. Further warming of the violet substance produces ozone in large quantities. Initiation of chemical reactions in this way, by warming the frozen material, indicates the possibility of opening up a new field of very low temperature chemistry. Because of the high chemical activity of the free radicals, new chemical compounds might be formed by this process.

Low-temperature condensates have also been obtained from hydrogen and water. Although the solids formed show complex behavior similar to that of nitrogen and oxygen, the results are not completely understood.

[1] *H. P. Broida and J. R. Pellam, Phys. Rev.* **95,** *845 (1954); H. P. Broida and J. R. Pellam, J. Chem. Phys.* **23,** *409 (1955).*

[2] *A. M. Bass and H. P. Broida, Phys. Rev.* **101,** *1740 (1956); H. P. Broida and O. S. Lutes, J. Chem. Phys.* **24,** *484 (1956).*

[3] *C. M. Herzfeld and H. P. Broida, Phys. Rev.* **101,** *606 (1955).*



A large, rapid temperature change is observed in the warmup curve of the solid nitrogen condensed from the gas discharge (a). This temperature rise is apparently due to the large amount of heat energy released by the nitrogen atoms as they recombine. Compare with warming curves for molecular nitrogen condensed without discharge (b) and the empty chamber (c). (d) Nitrogen vapor pressure curve.

Electron Physics Tables

A NEW publication, *Electron Physics Tables*, designed to facilitate the computations of scientists working with electrons, has just been issued.[1] It replaces the out-of-print and partly obsolete tables published in 1941.[2] Eight quantities are tabulated with 3,087 entries for each, in contrast to the four quantities with 1,400 entries each of the older tables. The new tables are arranged in parallel columns, so that when any one of the quantities is known, corresponding values of the other seven may be read off directly or by simple interpolation. Values are given with 8-figure accuracy, and cover a range of electron energies from 0.206 ev to 3.353×10^{12} ev.

The first quantity tabulated is V, the potential difference in absolute volts required to impart to an electron initially at rest a kinetic energy E expressed in electron volts. The second column gives V^*, the effective relativistic potential difference; i. e., it gives correct (relativistic) results when substituted for V in certain classical, nonrelativistic formulas. This makes it possible, for example, to find the relativistic momentum, p, from the nonrelativistic formula, $p=(2em_0V^*)^{1/2}$, where e and m_0 are the electron charge and rest mass, respectively. There is frequent use for V^* also in electron-optical calculations when using equations obtained from a Fermat-type variational principle in which momentum plays the roll of index of refraction.

Column 3 gives $H\rho$, the product of magnetic field, H, in oersteds, and the radius of curvature of electron path in centimeters. This quantity is used in experimental determinations of the electron momentum, to which it is related by the simple equation, $p=eH\rho$. The fourth quantity tabulated is λ, the de Broglie wavelength of the electron in the absence of a magnetic field; according to the well known definition, it is equal to h/p, where h is Planck's constant. Values of p^*, the momentum of the electron measured in units of m_0c, where c is the velocity of light, are listed in column 5. The convenience of this quantity for numerical calculations has often been pointed out in the literature.

The kinetic energy, E, used in defining V (column 1) is not listed. Instead, column 6 gives values of E^*, defined as equal to E/m_0c^2. E^* is therefore the kinetic energy of the electron measured in units of its rest energy, m_0c^2. The total energy of the electron, W^*, also measured in units of the rest energy, is tabulated in the next column. The last column contains β, the ratio of the electron velocity to the velocity of light.

In order to obtain 8-figure accuracy, SEAC calculated the values to several more than 8 figures, the excess digits being dropped at the end of the calculation. However, because of possible inaccuracies in the fundamental constants used, such as the velocity of light and the electronic mass and charge, the last 4 or 5 of the 8 digits may be uncertain. The 8 figures are given nonetheless, since the uncertainty in the fundamental constants does not affect the incremental steps between tabulated values; and these increments are often useful in themselves for the rapid evaluation of an experiment or theory.

[1] Electron physics tables, *by L. Marton, C. Marton, and W. G. Hall, NBS Circular 571, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., price 50 cents.*

[2] *These tables appeared as part II of* Miscellaneous Physical Tables: Planck's Radiation Functions and Electronic Functions, *Mathematical Tables 17 of the National Bureau of Standards (1941).*

Physical Mathematics

PHYSICISTS sometimes feel that conventional treatments of mathematical physics are not entirely satisfactory from the physical point of view. This is the position represented in the significantly titled new book by Chester H. Page, *Physical Mathematics* (D. Van Nostrand Co., Inc., Princeton, N. J.), which attempts simultaneously to attain increased generality and greater physical intuitiveness of results. This is accomplished, first, by giving primary emphasis to integration, making differentiation a derived concept. Second, the various approaches to the solution of classic problems in the field are correlated and their physical content elucidated. Thus, for example, the various ways of attacking the Helmholtz equation—the use of Hilbert space, Green's function, and integral equations—are viewed as providing different vantage points, analogous to different coordinate systems, for describing a common phenomenon.

In the opening chapter on integration and differentiation, as elsewhere, the stress is on physical interpretation. The equations for the vibrating string are then formulated and generalized to three dimensions. This leads to a study of eigenfunctions and eigenvalues and their geometrical interpretation. Classical special functions are investigated in connection with the representation of phenomena in different coordinate systems. Integral transform techniques (both Fourier and Laplace methods are described) are introduced when the discussion advances to a consideration of phenomena in unbounded regions. Finally, the connections between analytic complex functions and passive linear physical systems are developed and applied to the study of transients, heat flow, transmission lines, and Huygens' principle.

New Motion Picture

Porcelain Jacket Crown Technique, a 23-minute, 16-mm, sound and color film has been produced in cooperation with the American Dental Association and the University of Montevideo, Uruguay. It presents in detail a new simplified technique for preparing porcelain jacket crowns. For information regarding the loan or sale of this film (which is also available with Spanish narration) write to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

Accelerated Aging of Record Papers

THE BUREAU recently completed a 26-year experiment comparing accelerated aging tests of record papers with the effects of normal aging over long periods. Results of physical and chemical tests on papers aged in both ways show a fair correlation between natural and accelerated aging.[1]

Scientists have long sought, with varying degrees of success, to predict the useful life of materials by means of accelerated aging tests in the laboratory. While many such tests have been designed for various kinds of materials, correlation with results obtained in actual service has not always been satisfactory. Obviously, a reliable means of estimating the useful life of paper should be of value to libraries, archival agencies, life insurance companies, and other institutions keeping long-term records.

Accelerated aging of papers is usually carried out by holding the papers at an elevated temperature for some time. Since the rates of many chemical reactions are approximately doubled with each 10-degree (Celsius) rise in temperature, the use of higher temperatures provides, in general, a means of accelerating the aging process. However, this does not necessarily mean that the same reactions occur at higher temperatures as do at room temperatures. The correlation between accelerated and natural aging can only be determined by actual comparison of specimens aged in both ways. This requires storing specimens of the materials for several years and testing them periodically.

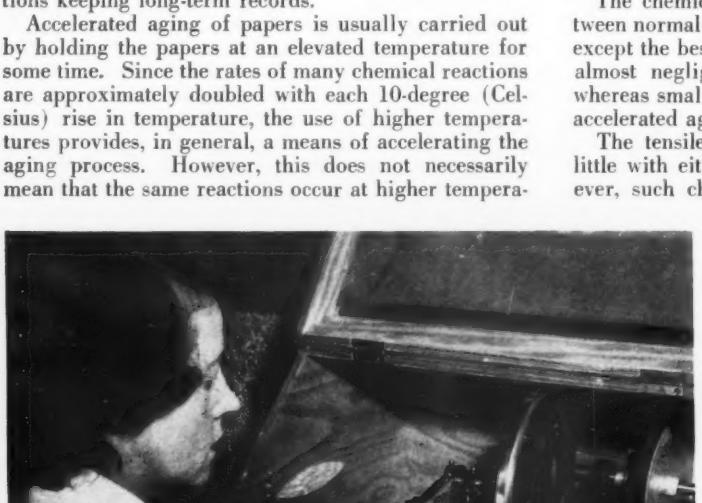
To provide the data for such a comparison, in 1928 the Bureau measured the physical and chemical properties of a series of papers before and after accelerated aging at 100°C for 72 hours.[2] At that time additional specimens for the papers were stored for normal aging and future testing. After 4 years [3] and again after 8 years [4] of normal aging, the stored specimens were tested for folding endurance; tensile strength; water-soluble acidity; *p*H; alpha-, beta-, and gamma-cellulose; and copper number. The chemical tests were repeated after 22 years and the physical tests after 26 years.

The papers included in the study were mostly commercial writing papers ranging in fiber content from 100 percent rag to 100 percent sulfite. Four soda-sulfite book papers were also included. The specimens were not exposed to unusual conditions of temperature, humidity, or air pollution during storage.

Statistical analysis of data on folding endurance gave some indication of the relationship between natural aging and accelerated aging. No quantitative conclusions could be drawn, as the manufacture and testing of paper had not progressed far enough in the late twenties to permit the proper control of variables in the selection of samples. However, logarithmic plots of natural and accelerated aging versus time indicated reasonably good correlation.

The chemical test data showed fair correlation between normal aging and accelerated aging of all papers except the best rag papers. Changes in the latter were almost negligible after 22 years of normal aging, whereas small but definite changes had occurred after accelerated aging.

The tensile strength of the papers decreased very little with either accelerated or normal aging. However, such changes as were observed did appear to show a correlation between the two types of aging. As the folding endurance decreased sharply for all types of papers, it is apparent that much greater changes occur in the fatigue characteristics of the papers than in the strength.



To measure folding endurance of paper, specimen (center of folding machine) is alternately folded, under 1 kilogram tension, until failure occurs. The total number of folds at time of failure is indicated on the small horizontal wheel behind and right of the specimen.

Any consideration of the permanence of paper must take into account both the stability of the cellulose and the structural stability, or stability of sheet formation. Cellulose permanence is independent of the sheet structure, but paper permanence depends both on cellulose stability and on the permanence of the sheet formation. Chemical tests are a measure of cellulose permanence while physical tests show the structure stability of the paper.

The chemical test data on the rag papers indicate very little deterioration in 22 years, but the folding endurance decreased, on the average, to less than half

of the original value. It thus appears that structural stability of the paper sheet decreases much more rapidly with aging than does the stability of the cellulose molecule.

[1] *For further details, see* Accelerated aging of record papers compared with normal aging, *by William K. Wilson, Jack L. Harvey, John Mandel, and Thelma Workman, TAPPI* **38,** *543 (1955).*

[2] A study of purified wood fibers as a paper-making material, *by Royal H. Rasch, BS J. Research* **3,** *469 (1929) RP107.*

[3] Comparison of natural aging of paper with accelerated aging by heating, *by Royal H. Rasch and B. W. Scribner, BS J. Research* **11,** *727 (1933) RP620.*

[4] Comparison of accelerated aging of record paper with normal aging for 8 years, *by B. W. Scribner, J. Research NBS* **23,** *405 (1939) RP1241.*

NUCLEAR LEVEL SCHEMES AND DATA CARDS

THE FIRST PART of a greatly revised and up-to-date edition of NBS Circular 499, *Nuclear Data,*[1] has recently been published under the new title, *Nuclear Level Schemes.*[2] The task of preparing the revised edition, in which the Bureau is cooperating, is being carried out by the Nuclear Data Group of the National Academy of Sciences—National Research Council. The project as a whole is sponsored by the Atomic Energy Commission.

The immediate purpose of such compilations as NBS Circular 499 and *Nuclear Level Schemes* is to make available in a single source the rapidly accumulating nuclear data from widely scattered published sources. The quantity of such data has risen steadily because of continued improvements in measurement techniques and increased use of particle accelerators. In 1947, for example, the annual cumulation of new nuclear data published in *Nuclear Science Abstracts* occupied 52 pages; in 1955 the number of pages required was 144.

Nuclear Level Schemes provides, in more comprehensive fashion than was possible at the time NBS Circular 499 was issued, a collection of diagrams showing positions and properties of nuclear energy levels and characteristics of radioactive decay and nuclear reactions. Experimental nuclear data are tabulated and there are extensive lists of references to original papers. The work is intended for two groups of users: those concerned with nuclear technology and nuclear scientists interested in the fundamental problems of nuclear structure.

The tremendous increase in experimental data since the appearance of Circular 499 has made it necessary to issue the new edition in sections. Section I, the only one published so far, is based on information available at the end of June 1955. It deals with all nuclei of mass number 40 to 92, inclusive, or roughly all elements from Ca through Zr. The remaining sections will deal with about 20 elements each and will be issued, so far as the complexity of the material permits, at intervals of a year. Nuclei of mass number less than 40 will be dealt with last of all, since compilations of data concerning them have recently been published elsewhere.[3]

There are a number of important differences between the new compilation and Circular 499. There is, first, the greatly increased quantity of data. Second, the basic arrangement is now by mass number instead of by atomic number. At the same time the level schemes for each group of radioactive isobars have been combined into a single diagram. By uniting the schemes in this way and drawing in the beta disintegrations connecting levels in parent and daughter nuclei, much information can often be deduced about the level spins and parities in the related nuclei.

Valuable as compilations like *Nuclear Level Schemes* are, something more is needed to keep up with the flood of new data. Thus, three supplements to Circular 499 had to be issued within two years; and in 1952 the AEC journal, *Nuclear Science Abstracts,* began publishing quarterly summaries of new results. In 1954, however, the Nuclear Data Group initiated what promises to be the most useful of such continuous supplementary services, the Nuclear Data Cards.[4] Subscribers to this service receive every month a set of about 150 3- by 5-inch cards, each containing new experimental results about a single nucleus. The cards have the special advantage that they may be filed not only according to mass or atomic number, but also according to halflife, cross section, energy of beta radiation, or any of the other nuclear properties reported in which the subscriber has a particular interest.

With the material made available by *Nuclear Level Schemes* and the Nuclear Data Cards, an important tool is placed in the hands of nuclear scientists. Designers of reactors can more easily survey the cumulated results about nuclear reactions and can keep abreast of new data on a month-by-month basis. The investigator of nuclear structure, on the other hand, can more easily check proposed theories against the experimental findings. When a theory is finally developed that will reliably predict the course of nuclear reactions and radioactive processes of all kinds, the ultimate purpose of the Nuclear Data Group's publications will have been accomplished.

[1] Nuclear data, *by K. Way, U. Fano, M. R. Scott, and K. Thew, National Bureau of Standards Circular 499 (1950) and three supplements (1950–1951).*

[2] Nuclear level schemes, A=40—A=92, *by K. Way, R. W. King, C. L. McGinnis, and R. van Lieshout (1955); available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. for $1.75.*

[3] Energy levels of light nuclei, *by F. Ajzenberg and T. Lauritsen, Revs. Mod. Phys. 27, 77 (1955);* Energy levels of light nuclei (Z=11 to Z=20), *by P. M. Endt and J. C. Kluyver, Revs. Mod. Phys.* **26,** *95 (1954).*

[4] *Available from Publication Office, National Academy of Sciences—National Research Council, 2101 Constitution Ave., Washington 25, D. C. Subscription rates, on calendar year basis only: $20.00 in U. S. and Canada, $30.00 elsewhere (foreign rate includes air mail postage); UNESCO coupons accepted. The supply of 1954 cards is exhausted.*

41st National Conference on Weights and Measures

THE Honorable Sinclair Weeks, Secretary of Commerce, was the principal speaker at the 41st National Conference on Weights and Measures held in Washington, D. C., May 21–25 under the sponsorship of the National Bureau of Standards. Speaking before the opening session of the conference, Secretary Weeks, in noting the dynamic condition of the nation's economy, paid special tribute to the work of the conference in breeding confidence in this economy.

Other speakers at this session were Dr. Allen V. Astin, Director of the National Bureau of Standards and President of the Conference, and Miss Genevieve Blatt, Secretary of Internal Affairs for the State of Pennsylvania. Honor award certificates were also presented at this session to delegates who had attended 10 or more conferences. The balance of the 4-day program was devoted to the presentation of technical papers and committee reports and general discussion. Total registration was 487, a new record for Conference attendance, with delegates representing state, county, and municipal weights and measures offices as well as business and industry.

The conference, which has been meeting in Washington since 1905, serves as a clearing house for weights and measures information, and develops and adopts model laws, specifications, tolerances, regulations, and enforcement practices that are recommended for enactment, promulgation, or adoption by the 48 states which have legal authority in the field of commercial weights and measures. The Bureau as custodian of the national standards of weights and measures has a basic interest in the conference. In this capacity, it cooperates with the various weights and measures offices in securing uniformity of weights and measures laws, methods of inspection, and testing as well as providing advisory service on scientific and technical problems.

The first day of the conference was devoted to open meetings of the standing committees. These meetings gave the delegates an opportunity to present their problems to the committees and to discuss recommendations made in tentative committee reports which had been distributed several weeks earlier. In action on the final day of the meeting, the delegates voted on the amendments contained in the committee reports which were distributed following the open meetings.

One entire session was devoted to a symposium on prepackaging, a commercial marketing technique of growing significance. In addition to a number of short papers, there were questions and a general discussion from the floor. Among the topics covered were quantity control in packages; labeling requirements under the Federal Food, Drug, and Cosmetic Act; prepacked meat; and packing house products. A completely new automatic prepackaging scale was also demonstrated to the delegates. Such machines may introduce into the retail food business quantity statements in decimal fractions of the pound instead of in ounces and fractions of ounces—the system now in use.

Among the more important actions by the conference was the adoption of a tentative code for liquefied-petroleum gas liquid-measuring devices. This action represents the first effort to develop a set of specifications, tolerances, and regulations for these commercial measuring devices which are playing an increasingly important role in the nation's economy. Also adopted were amendments to the specifications, tolerances, and regulations for commercial weighing and measuring devices previously adopted by the conference and published by the Bureau as Handbook 44—2nd Edition.

The Committee on Laws and Regulations introduced an amendment to the Model State Law on Weights and Measures concerning the adoption of performance requirements for devices which have been recommended by the Bureau. This committee also recommended methods of selling charcoal briquets, floor sweeping compounds, oysters, fertilizer for lawns, inert liquid fertilizer, lumber, rope and cordage products, packinghouse products, seeds, paint in color base tinting systems, crimping ribbon, and peat moss.

The Committee on Education discussed education of enforcement officials and the general public and recommended position descriptions in a weights and measures series. By accepting a report of the Committee of Vice Presidents, the conference nominated for 3-year terms on Weights and Measures Advisory Committee to the Director of the National Bureau of Standards, William A. Scheurer, Executive Vice President, Exact Weight Scale Company, Columbus, Ohio, and C. Morris Fuller, County Sealer of Weights and Measures, Los Angeles, California.

Formal papers presented during the meeting concerned many phases of a weights and measures program. Some of the subjects covered were obtaining evidence and preparing a case for court; quantity requirements under Federal alcohol and tobacco tax regulations; petrochemicals—their composition, handling, and quantity control; weights and measures report forms; food packages—when the responsibility of the state; state-city weights and measures cooperation; weights and measures training schools; quantity statements on wallpaper rolls; the meat packing industry trade practices; packaged food standardization; NBS railway track scale activities; and the current situation in highway axle-load weighing.

The initial showing of a new training film produced by the Bureau was a highlight of the conference. The 21-minute motion picture, *Testing Mass Standards by Substitution*, in color and with sound is available for loan or purchase on application to the Bureau.

Officers for the ensuing year were elected as follows: President: Dr. A. V. Astin, Director, National Bureau of Standards. Vice Presidents: M. A. Nelson, Michigan; J. E. Mahoney, Maryland; A. J. Mayer, Louisiana; J. C. Goll, North Dakota; C. J. Wills, Jr., Portland, Maine; R. K. Slough, Akron, Ohio. Secretary: W. S. Bussey, Chief, Office of Weights and Measures, National Bureau of Standards. Treasurer: G. F. Austin,

Jr., Detroit, Michigan. Chaplain: Rev. R. W. Searles, Medina County, Ohio. Sergeant at Arms: F. J. Delaney, Connecticut. Executive Committee: All of the officers, ex officio, and in addition, the following: A. H. Dittrich, New Hampshire; J. T. Kennedy, District of Columbia; Nalls Berryman, Florida; J. F. True, Kansas; C. H. Stender, South Carolina; E. L. Randall, Nevada; Norman Kirschbaum, Wisconsin; G. A. Pullman, Genesee County, New York; I. M. Levy, Chicago, Illinois; J. J. Powers, Philadelphia County, Pennsylvania; Tom Webb, Nashville, Tennessee; J. E. Bowen, Newton, Massachusetts; E. F. Moran, Providence, Rhode Island; F. G. Yarbrough, Dallas, Texas; S. H. Christie, Jr., New Jersey.

The 42nd National Conference on Weights and Measures will be held in Washington, D. C., June 3–7, 1957.

Note: The complete procedures of the conference are being published by the Bureau and are expected to be available within a few months. Meanwhile, multilithed copies of most of the papers presented are available from the NBS Weights and Measures Office on request.

Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, volume **57,** No. 1, July 1956 (RP2687 to RP2693 incl.). Annual subscription $4.00.

Technical News Bulletin, volume **40,** No. 7, July 1956. 10 cents. Annual subscription $1.00.

Basic Radio Propagation Predictions for November 1956. Three months in advance. CRPL 143. Issued July 1956. 10 cents. Annual subscription $1.00.

Journal of Research, volume **57,** *No. 1, July 1956. Single copies of the Journal vary in price. Single copies of Research Papers appearing in the Journal are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies of a Research Paper. Request for the purchase price should be mailed promptly to that office.*

RP2687. Mixed path ground wave propagation: 1. Short distances. James R. Wait.

RP2688. Effect of object frequency on focal position of four photographic objectives. Fred W. Rosberry.

RP2689. An examination of the 1955 helium vapor-pressure scales of temperature. E. Ambler and R. P. Hudson.

RP2690. Heats of formation of xonotlite, hillebrandite, and foshagite. E. S. Newman.

RP2691. Effect of camera tipping on the location of the principal point. Francis E. Washer.

RP2692. Mass spectra of some lead alkyls. Edith I. Quinn, Vernon H. Dibeler, and Fred L. Mohler.

RP2693. Frequency response of second-order systems with combined coulomb and viscous damping. T. A. Perls and E. S. Sherrard.

Circulars

C570. Units and systems of weights and measures. Lewis V. Judson. 25 cents.

C572. Calibration of line standards of length and measuring tapes at the National Bureau of Standards. Lewis V. Judson. 15 cents.

C574. Amplitude and phase curves for ground-wave propagation in the band 200 cycles per second to 500 kilocycles. James R. Wait and H. Herbert Howe. 20 cents.

Publications in Other Journals

Spectral absorption method for determining population "temperatures" in hot gases. Henry J. Kostkowski and Herbert P. Broida. J. Opt. Soc. Amer. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **46,** No. 4, 246–254 (Apr. 1956).

Spectra emitted from solid nitrogen condensed at 4.2°K from a gas discharge. Arnold M. Bass and Herbert P. Broida. Phys. Rev. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **101,** No. 6, 1740–1747 (Mar. 15, 1956).

Liquid-scintillator temperature effects. H. H. Seliger and C. A. Ziegler. Nucleonics. (Director of Circulation, 330 W. 42d St., New York 18, N. Y.) **14,** No. 4, 49 (1956).

Temperature studies of air in a truck tire. George Richey. Rubber Age. (Palmerton Publishing Co., Inc., 250 W. 57th St., New York 19, N. Y.) **79,** No. 2, 273 (May 1956).

Three ways to increase efficiency of liquid scintillators. C. A. Ziegler, H. H. Seliger, and I. Jaffe. Nucleonics. (Director of Circulation, 330 W. 42d St., New York 18, N. Y.) **14,** No. 5, 84–86 (1956).

Physical standards for the electronics industry. A. V. Astin. Signal. (1624 Eye Street, N. W., Washington 6, D. C.) **10,** No. 5, 45 (May–June 1956).

The calcium silicate hydrates. R. H. Bogue. (Research Director, Portland Cement Assoc. Fellowship, National Bureau of Standards, Washington 25, D. C.) Paper No. 69 (Sept. 1954).

Comparison of the characteristic energy losses of electrons with the fine structure of the X-ray absorption spectra. Lewis B. Leder, H. Mendlowitz, and L. Marton. Phys. Rev. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **101,** No. 5, 1460–1467 (Mar. 1, 1956).

Aerodynamical mechanisms producing electronic density fluctuations in turbulent ionized layers. R. M. Gallet. Proc. IRE (1 E. 79th St., New York 21, N. Y.) **43,** No. 10, 1240–1252 (Oct. 1955).

Infrared absorption spectrum of N-dimethyl-aminodiborane between 15 and 40 microns. James E. Stewart. J. Chem. Phys. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **23,** No. 11, 2204–2205 (Nov. 1955).

Durability of deaired brick. J. W. McBurney and Paul V. Johnson. J. Am. Ceram. Soc. (2525 N. High St., Columbus 2, Ohio) **39,** No. 5, 159–168 (May 1, 1956).

High-gain antennas for VHF scatter propagation. H. V. Cottony. Inst. Radio Engrs. Trans. (1 E. 79th St., New York 21, N. Y.) **CS–4,** No. 1, 56–62 (1956).

Atomic radiation and polymers. L. A. Wall. Soc. Plastics Engrs. (Jesse H. Day, 409 Security Bank Bldg., Athens, Ohio) **12,** No. 3, 17–20 (Mar. 1956).

A paper chromatographic analysis for collagen and collagen derivatives. James M. Cassell. J. Am. Leather Chemists' Assoc. (Fred O'Flaherty, Dept. of Leather Research, Univ. of Cincinnati, Cincinnati 21, Ohio) **51,** No. 5, 223–234 (May 1956).

Measurements on the saturation vapour pressure of liquid helium in the range 1.4° K–4.2° K. E. Ambler and R. P. Hudson, Bul. Inter. Inst. Refrig. (177 Blvd. Malesherbes, Paris (17e) France) Commun. **147,** 605 (Sept. 2–8, 1955).

High-speed machine computation of ideal gas thermodynamic functions. I. The isotopic water molecules. Abraham S. Friedman and Lester Haar. J. Chem. Phys. (57 E. 55th St., New York 18, N. Y.) **22,** No. 12, 2051 (Dec. 1954).

High-speed machine computation of ideal gas thermodynamic functions. II. The diatomic free radicals of the isotopic hydrides of oxygen and sulfur. Lester Haar and A. S. Friedman. J. Chem. Phys. (57 E. 55th St., New York 22, N. Y.) **23,** No. 5, 869 (1955).

Electron affinity of atomic oxygen. Lewis M. Branscomb and Stephen J. Smith. Phys. Rev. (57 E. 55th St., New York 22, N. Y.) **98,** No. 4, 1127 (1955).

Experimental cross section for photodetachment of electrons from H— and D—. Lewis M. Branscomb and Stephen J. Smith. Phys. Rev. (57 E. 55th St., New York 22, N. Y.) **98,** No. 4, 1028 (1955).

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Contents

	Page
X-ray studies of stresses in metal	105
The Petrel	108
Forward scatter addendum	108
Stress-corrosion cracking of brass	109
Direct measurement of dynamic bulk modulus	110
Low-temperature storage of free radicals	112
Electron physics tables	115
Physical Mathematics	115
New motion picture: Porcelain jacket crown technique	115
Accelerated aging of record papers	116
Nuclear level schemes and data cards	117
41st National Conference on Weights and Measures	118
Publications of the National Bureau of Standards	119

NBS Publications (*continued*)

Understressing as a means of eliminating the damaging effect of fatigue stressing. H. E. Frankel and J. A. Bennett. ASTM Bull. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) **55,** 891 (1955).

The behavior of long helical springs under fluctuating load. C. L. Staugaitis and H. C. Burnett. ASTM Bull. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) **55,** 918, (1955).

The effect of an anodic (HAE) coating on the fatigue strength of magnesium alloy specimens. J. A. Bennett. ASTM Bull. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) **55,** 1015 (1955).

A one-microsecond adder using one-megacycle circuitry. A. Weinberger and J. L. Smith. Inst. Radio Engrs. Trans. Electronic Computers. (American Inst. of Electrical Engineers, 33 W. 39th St., New York 18, N. Y.) **EC–5,** No. 2, 65–73 (June 1956).

On the conductance of slots. J. R. Wait. Inst. Radio Engrs. Trans. Antennas and Propagation. (American Inst. of Electrical Engineers, 33 W. 39th St., New York 18, N. Y.) **AP–4,** No. 2, (April 1956).

Abundance of free atoms in solid nitrogen condensed at 4.2° K from a gas discharge. H. P. Broida and O. S. Lutes. J. Chem. Phys. (American Inst. of Physics, Inc., 57 E. 55th St., New York 22, N. Y.) **24,** No. 2, 484–485 (Feb. 1956).

Electron optical image of an atomic beam. L. Marton, D. C. Schubert, and S. R. Mielczarek. J. Appl. Phys. (American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) **27,** No. 4, 419 (April 1956).

Low frequency radiation from a horizontal antenna over a spherical earth. James R. Wait. Can. J. Phys. (Div. of Admin. National Research Council, Ottawa 2, Canada) **34,** 586–595 (1956).

How the National Bureau of Standards contributes to building codes. James P. Thompson. BOCA News (Building Officials Conference of America, Inc., 110 E. 42nd St., New York 17, N. Y.) **4,** No. 12, 1–3 (May 1956).

Linear programming in bid evaluation. E. D. Stanley, D. P. Honig, and Leon Gainen. Naval Research Logistics Quarterly. (Supt. of Documents, Government Printing Office, Washington 25, D. C.) **1,** No. 1, 48–54 (March 1954).

Attenuation of 86- and 176-Mev synchrotron X-rays in concrete and lead. William Miller and Robert J. Kennedy. Radiation Research. (Academic Press Inc., 125 E. 23d St., New York 10, N. Y.) **4,** No. 5, 360–365 (May 1956).

Some computational problems in algebraic number theory. Olga Taussky. Proc. Sixth Symposium Appl. Math. Am. Math. Soc. (McGraw-Hill Book Co., Inc., 330 W. 42d St., New York, N. Y., August 1953).

Cycle strain tester for leather. T. J. Kilduff and J. R. Kanagy. J. Am. Leather Chemists' Assoc. (Univ. of Cincinnati, Cincinnati 21, Ohio) **50,** No. 10, 489 (1955).

Magnetic cooling. E. Ambler and R. P. Hudson. Proc. Phys. Soc. (London) (1 Lowther Gardens, Prince Consort Rd., London SW7, England) **18,** 251 (1955).

Specular-gloss measurement of ceramic materials. I. Nimeroff, H. K. Hammond, III, J. C. Richmond, and J. R. Crandall. J. Am. Ceram. Soc. (2525 N. High St., Columbus 2, Ohio) **39,** No. 3, 104–109 (Mar. 1956).

Studies on leather by means of a sonic technique. Joseph R. Kanagy and Myron Robinson. J. Am. Leather Chemists' Assoc. (Fred O'Flaherty, Dept. of Leather Research, Univ. of Cincinnati, Cincinnati 21, Ohio) **51,** No. 4, 174–197 (Apr. 1956).

Metrology and production. Allen V. Astin. Ordnance (American Ordnance Assoc., 708 Mills Bldg., Washington 6, D. C.) **40,** No. 216, 973–974 (May–June 1956).

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Page
105
108
108
109
110
112
115
115
115
116
117
118
119